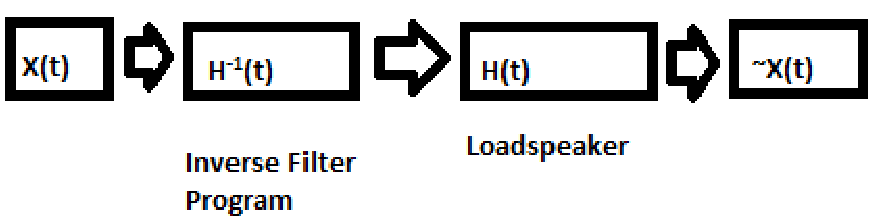
Loud Speaker Equalization Project Overview
ELEC 301 Project Loud Speaker Equalization Overview

Loudspeaker Equalization

Overview

A loudspeaker converts sound from its electric form to an audible form. In doing so it introduces notable distortions (in both magnitude and phase) in the sound thus leading to poor sound quality. Under the assumption that the speaker behaves somewhat linearly, loudspeaker equalization has been developed to deal with such distortions and minimize them to a great extent. Loudspeaker equalization involves processing and correcting the frequency response of a loudspeaker so that the spectrum of the resulting output is close to the spectrum of the input. One way to implement loudspeaker equalization is to use MATLAB fir design tools and the TI 3245 EVM which has a built in FIR filter.

To find the frequency response of a speaker one can play white noise through the loudspeaker and record it onto a computer. The recording is then processed in MATLAB with the attached code to generate a frequency response of the white noise. Next invert the frequency response to find an ideal inverse filter to correct for the distortion of the speaker and give the system an overall flat frequency response. Finally use MATLAB's fir2 design tool to create a length 64 fir filter which we can be implemented onto the TI chip.



Objectives:

1. Find an accurate frequency response for the loudspeaker.

2. Invert this frequency response to get the inverse filter.

3. Implement it on the chip.

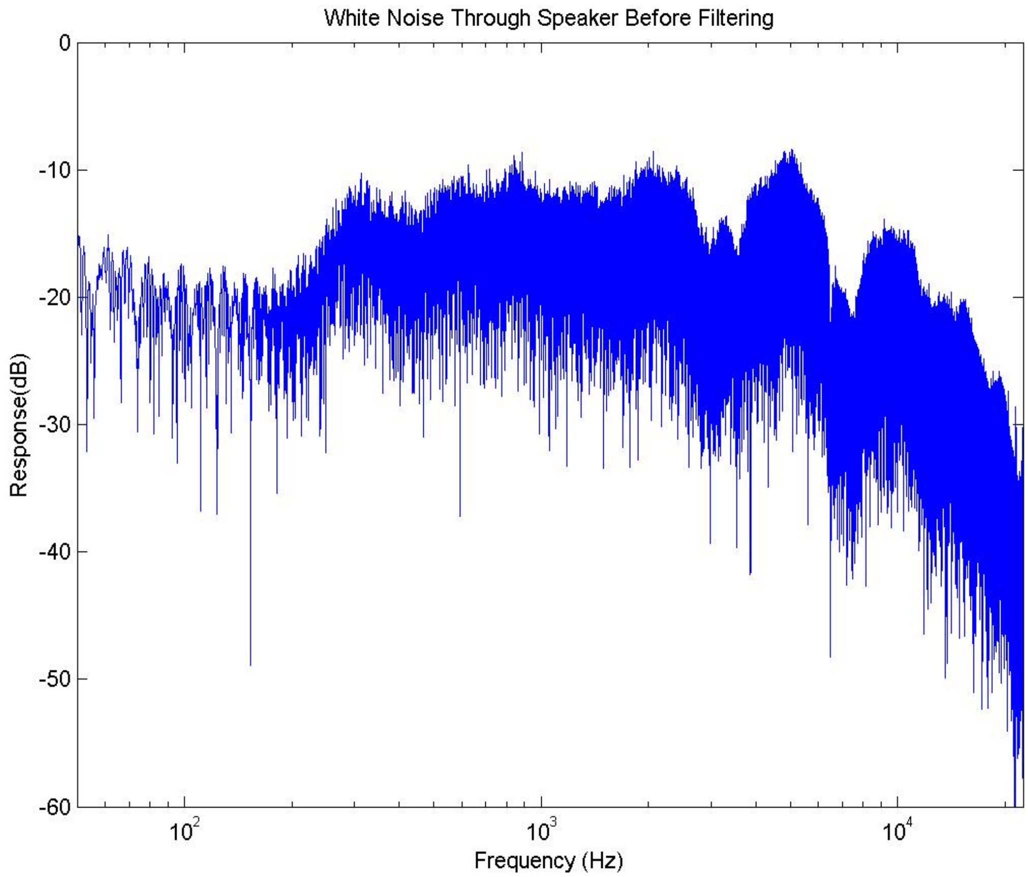
4. Verify the speaker sounds better.

Frequency Response
Elec 301 Project procedure part 1: Obtaining the Frequency Response

Procedure:

1. Frequency response:

The frequency response of the speaker describes everything from low frequency resonance to high frequency distortion. One of the ways to find a frequency response of a speaker is to blast white noise through the speaker and record the result. White noise contains all frequencies and thus can be used to describe the speaker's response to any input signal. To obtain the frequency response of a speaker, generate white noise and record the response and then use Matlab's fft command and a log log plot to view the response.

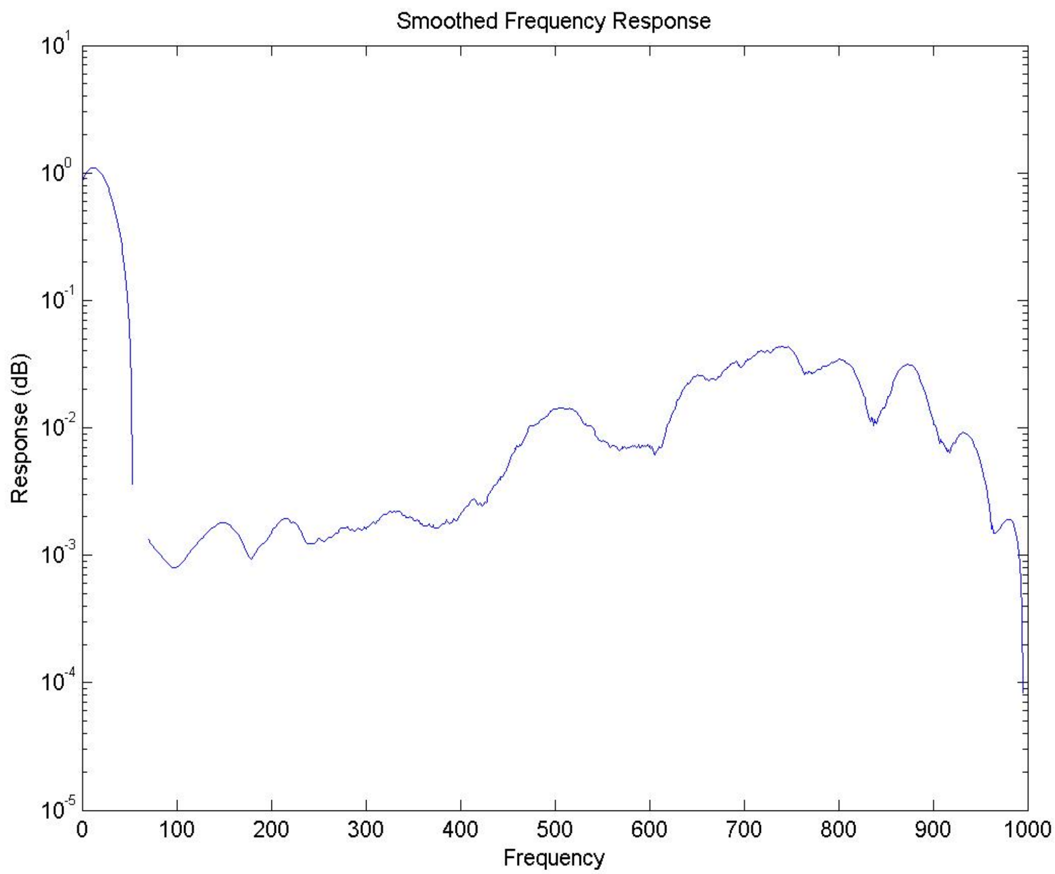


The resulting frequency response describes the speaker but is very noisy.

Sampling and Smoothing
ELEC 301 Project Procedure Part 2: Sampling and Smoothing Frequency Response

2. Sampling and Smoothing the Response.

Next sample the frequency response logarithmically so that low frequencies will be weighted more importantly by the filter. This allows the logarithmic plot of an ideal inverse filter and the inverse filter implemented by FIR coefficients to match (rather than matching only high frequencies). Next use MATLAB's built in Savitzky Golay [y = sgolayfilt(x,k,f)] filter to smooth the curve so as to reduce the noise of the response. The motivation behind this was is to prevent the fir2 algorithm from trying to create an inverse filter with the inverse of the noise of the frequency response.



```
sampfft=thisfft(round(10.^(linspace(0,log10(length(thisfft)),1000))));
%sample fft logrithmicly at 1000 points

smoothfft=sgolayfilt(sampfft, 3, 71);

smoothfft(smoothfft<0)=0; %fix smoothing errors

semilogy(smoothfft)

title('Smoothed Frequency Response');

xlabel('Frequency');

ylabel('Response (dB)');
```

Low Frequency Resonance
ELEC 301 Project Procedure Part 3: Low Frequency Resonance

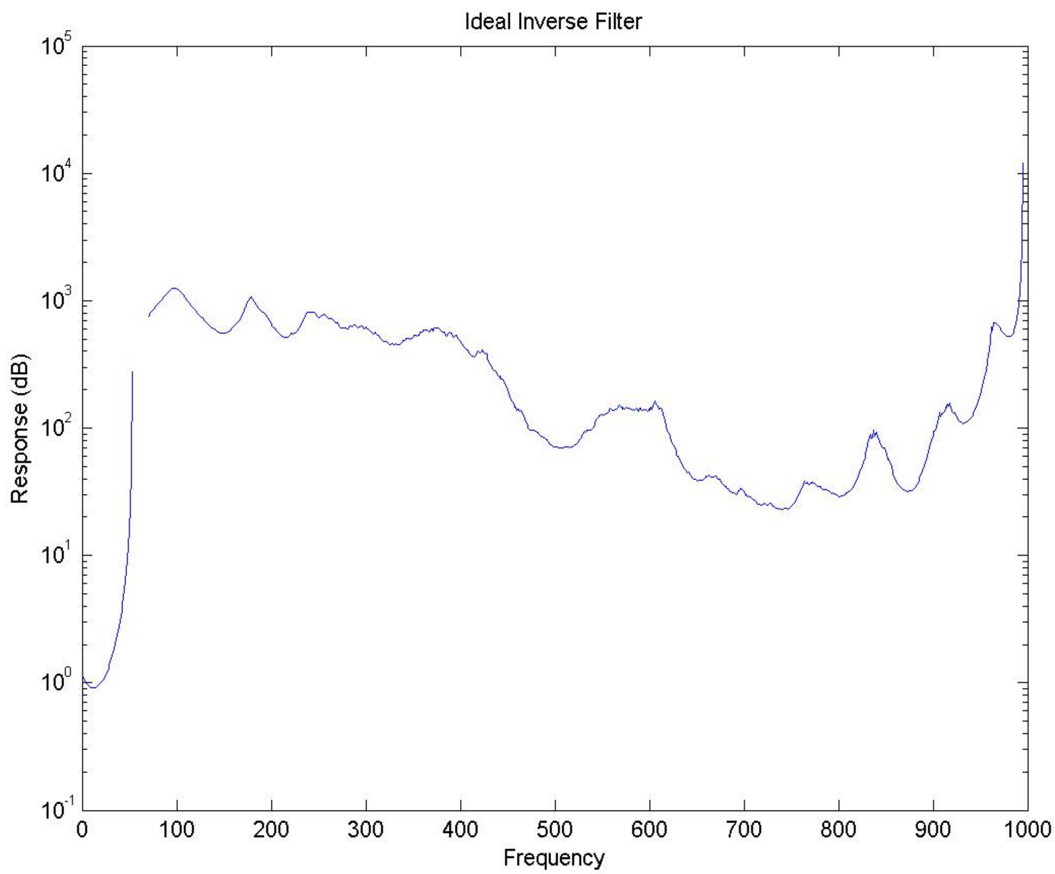
3. Low Frequency Resonance:

The resonant frequency of a loudspeaker is the frequency at which it is most susceptible to an electric response and any departure from this frequency causes the response to drop sharply. Because it is difficult to flatten such large peaks and valleys located next to one another, it’s necessary to highpass filter the input to remove all frequencies at and below the resonant frequency. In the exemplar speaker, the resonant frequency zone was identified by a small bump followed by sharp drop in the frequency response at ~500 Hz.

Inverting the Response
ELEC 301 Project Procedure Part 4: Inverting the Response

4. Inverting the Response

After smoothing and logarithmically sampling the frequency response of a speaker one only has to invert this data to create an ideal inverse filter for the speaker. Simply flip the frequency response of the loudspeaker over the frequency axis and scale it appropriately.



targetfft=(1./smoothfft);

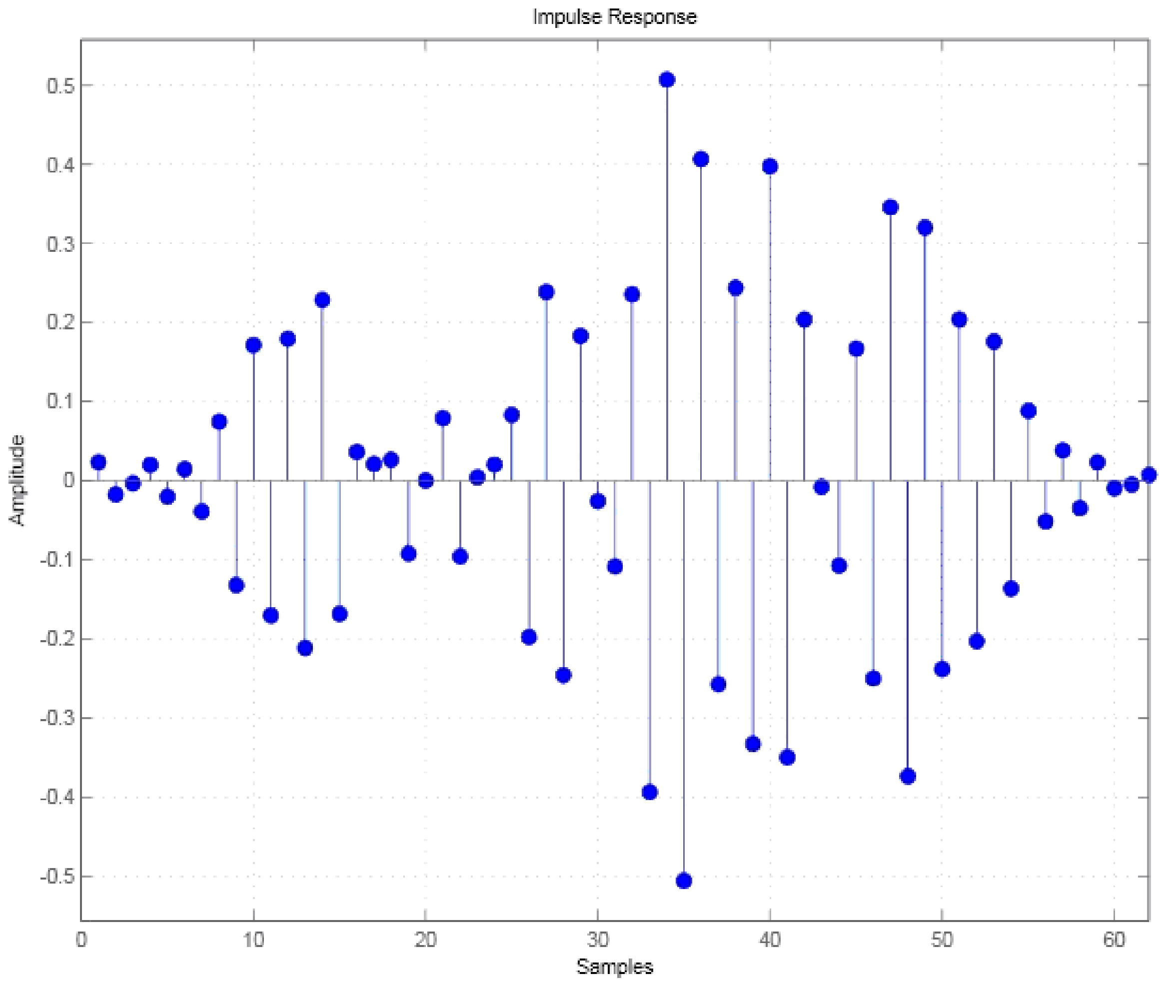
semilogy(targetfft)

```
title('Ideal Inverse Filter');
xlabel('Frequency');
ylabel('Response (dB)');
```

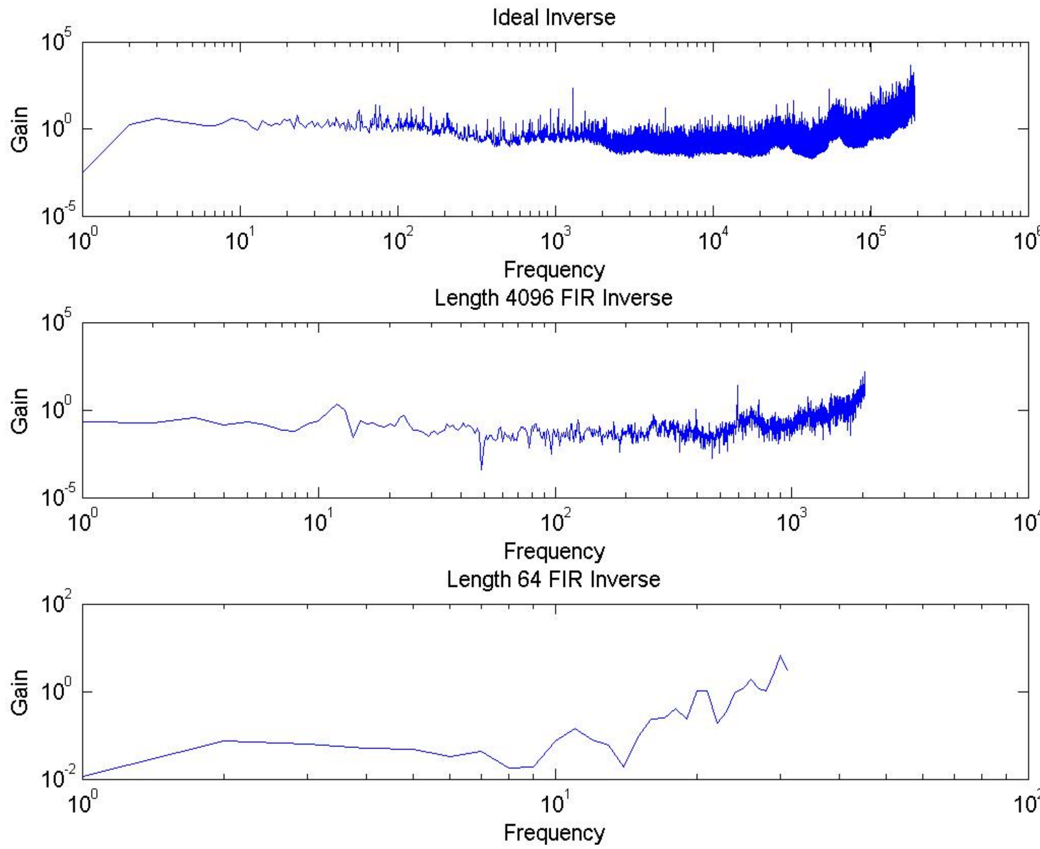
FIR Filter on TI Chip
ELEC 301 Project Procedure Part 5: FIR Filtering

5. FIR Filter on the TI Chip.

To create a FIR filter which matches a desired inverse filter, use the built in MATLAB filter design program called fir2 [b = fir2(n,f,m)]. This designs an n order FIR filter which attempts to create an FIR filter whose spectrum matches a linear interpolation between input amplitudes m at frequencies f. The coefficients (b) are obtained by applying an inverse Fourier transform to m at frequencies f and multiplying by a window. In creating an inverse filter, the default Hamming window is acceptable because it provides a balance between the dynamic range and the resolution of the signal. The response of the inverse filter at different frequencies should not be so different that a huge dynamic range is required. Finally enter these coefficients into the TI chip and produce an FIR filter.




```
h=fir2(62, ((10.^(linspace(0,1,length(targetfft))'))-1)/9,targetfft);
```

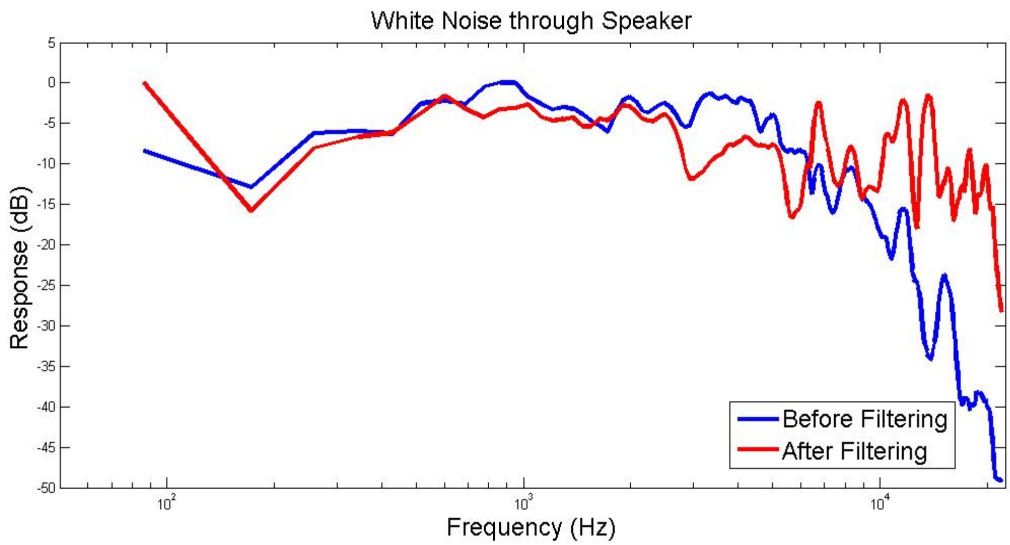


The FIR2 command with 64 coefficients does an acceptable job of matching the shape of an ideal inverse filter. However, given more memory and more coefficients one could do any even better job of matching the ideal.

Frequency Response Correction Verification
ELEC 301 Project Procedure Part 6: Verification

6. Verification

Finally to verify that the inverse filter works, play white noise through the speaker again and record the response with and without the filter.



The filter isn’t able to completely flatten the frequency response but it does smooth it significantly, especially at higher frequencies.

Loud Speaker Equalization Project Conclusions
ELEC 301 Project Conclusions

Conclusion: Get a Better Mic

Using white noise and MATLAB’s FIR design tools successfully implements an inverse filter on TI’s 3245 EVM which flattens the systems frequency response. Unfortunately, when music was played through the exemplar speaker, various high frequencies would be over-amplified, creating hissing. Throughout the design of its inverse filter a relatively low end microphone, designed primarily to pick up speech signals, was used. After comparing what the frequency response of our system looks like compared to how it actually sounds, it’s clear it was the microphone itself that was causing the attenuation of higher frequencies. Thus by amplifying higher frequencies, the inverse filter flattened the frequency response of the system but spoilt the frequency response of the speaker.